STATE OF WASHINGTON
Daniel J. Evans, Governor

DEPARTMENT OF CONSERVATION
Roy Mundy, Director

DIVISION OF WATER RESOURCES
Murray G. Walker, Supervisor

Water Supply Bulletin No. 18

Water Resources and Geology of the Kitsap Peninsula and Certain Adjacent Islands

By

M. E. Garling, Dee Molenaar and others
with contributions by the
UNITED STATES GEOLOGICAL SURVEY

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Price $2.00, Division of Water Resources, Olympia, Wn. 98502

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WATER RESOURCES AND GEOLOGY OF THE KITSAP PENINSULA AND CERTAIN ADJACENT ISLANDS

ABSTRACT

The Kitsap Peninsula and certain adjacent islands, with a land area of 668 square miles, are located in central western Washington. Bounded on nearly all sides by marine waterways of the Puget Trough, the report area includes all of Kitsap County and portions of Mason, Pierce and King Counties. With an increasing growth rate since World War II, 1962 census figures show an estimated population of 105,000 persons. This amounts to a density of 157 persons per square mile, more than 3.6 times the state-wide average.

The report area has basically a maritime climate, with mild, wet winters, and cool, dry summers. Precipitation is moderate in the southern part of the area, while the northern part of the Kitsap Peninsula, lying more directly in the rain shadow of the Olympic Mountains, receives considerably less rainfall. Mean annual precipitation ranges from about 26 inches in the north to nearly 80 inches in the vicinity of Green and Gold Mountains in the central part of the study area.

The land surface of the Kitsap Peninsula consists primarily of low rolling hills which are remnants of a glacial drift plain. The original plain, underlain by unconsolidated sands, gravels, silts and clays which were deposited by successive glaciers entering the Puget Trough from the north, has been modified and dissected both by glacial and stream erosion, and by wave action.

Rocks in the report area range in age from Tertiary to Recent, the oldest being a thick sequence of basaltic lava flows which are equivalent of the Metchosin volcanics of Eocene age. Overlying the volcanic rocks is the Blakeley Formation of Oligocene age, composed primarily of marine sandstone, shale and conglomerate. These sedimentary rocks are exposed along the shorelines of Port Washington Narrows and Rich Passage north and east of Bremerton, and on the south end of Bainbridge Island. The Blakeley Formation is overlain by thick layers of material consisting of unconsolidated to semiconsolidated sand, gravel, silt and clay which comprise the glacial and interglacial deposits of the Pleistocene Epoch. A mantle of soil, peat, and other Recent alluvial materials, from a few inches to several feet in thickness, overlies most of the report area.

Sufficient ground water for domestic purposes is available from wells in nearly all parts of the study area. In many places domestic supplies are developed from shallow dug wells tapping perched ground water in the recessional outwash materials which overly the relatively impermeable Vashon till. Most of the drilled wells in the report area obtain moderate supplies of ground water from the sands and gravels of the advance outwash and Colvos Sand which underlie the Vashon till. The aquifers with the greatest potential for future development of moderate to large supplies are the coarse sands and gravels of the Salmon Springs(?) Drift which is present at greater depths beneath most parts of the report area. The pre-Salmon Springs(?) deposits, undifferentiated, consist predominantly of massive blue-gray clay and are, therefore, not considered as a potential source for development of large amounts of ground water. Several wells have penetrated the Blakeley Formation but the limited amount of water obtained was generally of poor quality. Due both to the lack of readily available surplus waters and to unfavorable geologic conditions it is improbable that an extensive artificial ground-water recharge program would be suitable in the report area.

As a result of its irregular shape, only a few major stream systems have developed on the Kitsap Peninsula. Most of the study area is drained by many small, relatively short streams that discharge directly into the surrounding marine waters. A study of topographic maps and field investigations disclosed a total of 582 separate stream systems in

the area, of which only 12 have drainage areas exceeding 10 square miles.

Basically similar flow patterns are displayed by most of the streams and, essentially, the variations in flow closely follow the seasonal trend of precipitation. In winter, precipitation occasionally occurs in the form of snow but generally warm temperatures prevent accumulation and the effect of snow storage on streamflow is insignificant. The highest flows are produced by direct runoff following winter storms, whereas low flows, sustained by ground-water effluent, occur during the precipitation deficient summer months.

Both streamflow records and geology indicate that ground-water contributions to streamflow vary considerably throughout the area. Aquifers are commonly continuous across topographic divides, permitting the ground waters of certain basins to migrate to adjacent drainages. Because most drainages are small, little flood damage has occurred in the area.

The flow characteristics of major streams in the area were analyzed from available records and the results are graphically presented in terms of daily-discharge hydrographs, bar charts of monthly discharge, discharge-duration curves, and discharge-duration hydrographs. Various statistics derived from the data show that the variability of annual runoff throughout the report area is generally low and the yield of most streams is quite consistent from year to year. Using the entire period of record for each gage, coefficients of variation for annual runoff range from a low value of about 11 percent for Dewatto Creek to a high value of 26 percent for Huge Creek.

The chemical quality of ground water in the study area is generally adequate for most uses. Measured dissolved-solids contents range from 64 to 346 ppm. However, about 80 percent of the values are less than 150 ppm, and include mostly silica, calcium, magnesium, and bicarbonate. Almost all sampled ground water from the Colvos Sand and younger units contains less than 100 ppm of dissolved solids, whereas water in the Salmon Springs(?) Drift and older formations characteristically contains more than 100 ppm. Concentrations of potassium and phosphate also show characteristic differences from unit to unit, and they can be used in combination with the dissolved-solids content to determine the geologic source of ground water on the peninsula and adjacent islands. Measured hardness-of-water values are as great as 190 ppm, but most of the ground water is soft or only moderately hard (less than 120 ppm). Iron in solution at the time of sample collection was as great as 0.62 ppm, but most water containing more than 0.30 ppm is restricted to the northeastern and southeastern parts of the study area.

Deterioration of ground-water quality may soon become an important factor in some parts of the peninsula and adjacent islands because of increased withdrawals in areas subject to contamination by waters of undesirable quality from deeper aquifers or from the Puget Sound.

Stream and lake water in the study area characteristically contains smaller amounts of dissolved solids than the ground water. For streams, this is especially true during periods of high flow. (During low flow, the streams more nearly resemble ground water chemically because spring flow provides much of the surface-water discharge during such periods.) The surface water is suitable for most uses throughout much of the year. However, streams in the eastern part of the study area carry large amounts of highly colored dissolved organic material during periods following abundant rainfall.

INTRODUCTION

This study of the Kitsap Peninsula and certain adjacent islands was made by the Division of Water Resources of the Washington State Department of Conservation, with contributions by the U. S. Geological Survey. The report is part of an overall inventory of the State's water resources being conducted by the Division of Water Resources under the general direction of Murray G. Walker, Supervisor, and under the direct supervision of Robert H. Russell, Assistant Supervisor. The sections of the report contributed by the U. S. Geological Survey were prepared under the general supervision of Fred M. Veatch, District Engineer of the Surface-Water Branch, Tacoma, Washington, and Les B. Laird, District Chemist of the Quality of Water Branch, Portland, Oregon.

The sections of the report prepared by the Division of Water Resources are authored by Dee Molenaar, Geologist; M. E. Garling, Hydraulic Engineer; and G. H. Fiedler, Hydraulic Engineer. Authors of the sections contributed by the U. S. Geological Survey are E. G. Bailey, Hydraulic Engineer and A. S. Van Denburgh, Geologist. Specifically, the major areas of contribution and responsibility are as follows:

Robert H. Russell.....	Project Supervisor
Dee Molenaar.........	Physical description, Economics of the region and Geology and ground-water resources
M. Edward Garling	Climate, Economics of the region, Streamflow characteristics, Evaluation of the surface-water supply, Water development sites and Water appropriation
Earl G. Bailey........	Basic streamflow data and Floods in the report area
A. S. Van Denburgh...	Water quality
Glen H. Fiedler.......	Water rights and water law

For clarity of reference, authorships are also indicated under the title of each major section of the report.

PURPOSE AND SCOPE OF THE INVESTIGATION

Since the close of World War II the Kitsap Peninsula area has experienced a steadily increasing demand for industrial, irrigation and domestic water supplies. Since completion of the Tacoma Narrows Bridge and the Hood Canal Floating Bridge in the southern and northern parts of the Peninsula area, respectively, and with the possible future construction of one or more across-Puget Sound bridges further linking the Peninsula with the mainland, it is evident that there will be a rapid acceleration in the area's economic growth and demand for additional water. To adequately meet the water needs for the expected expansion, a thorough knowledge of the water resources is required.

In planning and compiling information for this report, the authors have tried to answer the following questions:

1. What are the quantitative and qualitative characteristics of the surface and ground-water resources of the area under study?
2. What is the present known demand against the total water resource?
3. How much water is still available for appropriation and where are these supplies located?
4. How much additional water can be made available through the development of surface-water storage reservoirs, and what is the feasibility of artificial recharge of ground-water reservoirs?

Work was started on the Kitsap Peninsula study in October, 1960, and was completed in June, 1963. The study consisted of a compilation of existing data, a thorough evaluation of previous works, and geologic and hydrologic mapping of areas which had not been previously mapped in detail. Existing information was modified and updated with more recent findings.

Because only limited basic data were available on water quality in the report area prior to the start of the project, additional samples of both surface and ground water were collected for this study. With the resulting information, efforts were made to correlate the chemical constituents of ground waters to the geologic formations from which they were obtained, and, likewise, to correlate surface waters to the materials across which they flowed.

The data presented herein are designed to assist engineers, geologists, and hydrologists, as well as municipal, county, state and federal agencies who are actively associated with the planning and development of water resource projects.

LOCATION AND EXTENT OF AREA

The area under study includes approximately 668 square miles of land located entirely within the Puget Sound lowland in west-central Washington State (fig. 1). It is bounded on the west by Hood Canal and Case Inlet, on the north and east by Admiralty Inlet and Puget Sound, respectively, and on the south and southeast by southern Case Inlet, Nisqually Reach, Cormorant Passage and the Narrows. The area includes all of Kitsap County (402 square miles), and parts of Mason County (108 square miles), Pierce County (121 square miles), and King County (37 square miles). The report covers 15 islands, with McNeil and Ketron Islands being included for cursory surface-water studies only. The total insular area studied covers 86.3 square miles and a total of the peninsular areas covers 581.8 square miles. The project area lies within Townships 19 through 28 North and Ranges 3 West through 3 East, Willamette Meridian.

PREVIOUS INVESTIGATIONS

Since the 1890's several studies of the geology and hydrology of the Puget Sound lowland have included all or parts of the area of this report. In most cases, however, the previous works referred only generally to the area encompassed by the present report, or dealt with specific problems of limited areal scope.

The earliest geologic investigation which included the study area was made by Bailey Willis. In 1898 Willis described some of the glacial drift stratigraphy of the Puget Sound region. In 1913, J Harlan Bretz described the glaciation of the Puget Sound lowland.

A soil survey of Kitsap County was conducted and a report by Robert Wildermuth and others (1939) describes the various soil types which mantle the county.

Surface water supply papers of the U. S. Geological Survey and Water Supply Bulletins No. 6 and No. 15 of the Washington State Division of Water Resources provide daily, monthly and annual streamflow data for streams in the State of Washington. Data relating to size of drainage areas of Western Washington, as measured above the sites where discharge measurements have been made, were compiled by Donald Richardson (1962) of the U. S. Geological Survey. E. E. Wolcott (1961) of the State Division of Water Resources describes the lakes of western Washington which include all named lakes and unnamed lakes of one acre or more in area within the study area.

Several investigations have been made of geologic and hydrologic conditions within specific parts of the study area. These include an open-file report by A. M. Piper (1930) which discusses water-supply possibilities for use by the U. S. penitentiary on McNeil Island, a report by Howard Coombs (1955) which discusses the geology of the Union River dam site for the City of Bremerton, and a report by R. W. Beck and Associates (1960) which discusses a preliminary engineering study of the Gold Creek reservoir site and distribution route for the Kitsap County Public Utility District No. 1.

The previous geologic and ground-water study most important to this report was that made of Kitsap County proper by J. E. Sceva(1957) of the U. S. Geological Survey. Sceva's work provided the basis for extension of the geologic mapping to include the entire Kitsap Peninsula and certain adjacent islands. Minor modifications were made of Sceva's mapping of Kitsap County, and some stratigraphic units were renamed upon the basis of correlation with more recently examined late Pleistocene deposits in other parts of the Puget Sound lowland. This report incorporated a part of Sceva's information on well logs into updated tabulations.

CONCURRENT STUDIES

During the course of this investigation, two concurrent studies were being made in adjacent areas. Noble and Wallace (in preparation) of the Division of Water Resources, geologically mapped Thurston County to the south and Walters and Kimmel (in preparation) of the U. S. Geological Survey mapped part of Pierce County to the east. These authors exchanged ideas with the result that many complex geologic and stratigraphic problems common to all areas were better understood and correlated.

ACKNOWLEDGMENTS

The writers wish to acknowledge assistance rendered by a number of individuals and agencies without which this report could not have been completed.

Harbor Drilling Company of Gig Harbor, Reliable Drilling Company of Bremerton, Stoican Drilling Company of Port Orchard, and Pioneer Drilling Company of Seattle all furnished drillers' logs and pump test data for many wells located within the study area.

Robinson and Roberts, Ground-Water Geologists, Tacoma, and staff members of the U. S. Geological Survey, Ground-Water Branch, Tacoma, were very helpful in furnishing data and comment on geohydrologic problems. Special thanks is due Dr. J. Hoover Mackin, Department of Geology, University of Texas, for his assistance in interpretation of complex stratigraphic problems.

Personnel of the state and county health departments were very helpful in supplying water quality data and information on water systems serving the public. The Chambers of Commerce of Port Orchard and Winslow were helpful in furnishing information on population and economics of the area. Everett G. Humble, Superintendent of the City of Bremerton Water Department, furnished data on the city's municipal water supply system.

Information about the area's fishery resources was furnished by personnel of the State Departments of Fisheries and Game.

In addition, the authors owe thanks to the many well owners, operators of community water-supply systems, and others who furnished data but are too numerous to cite individually.

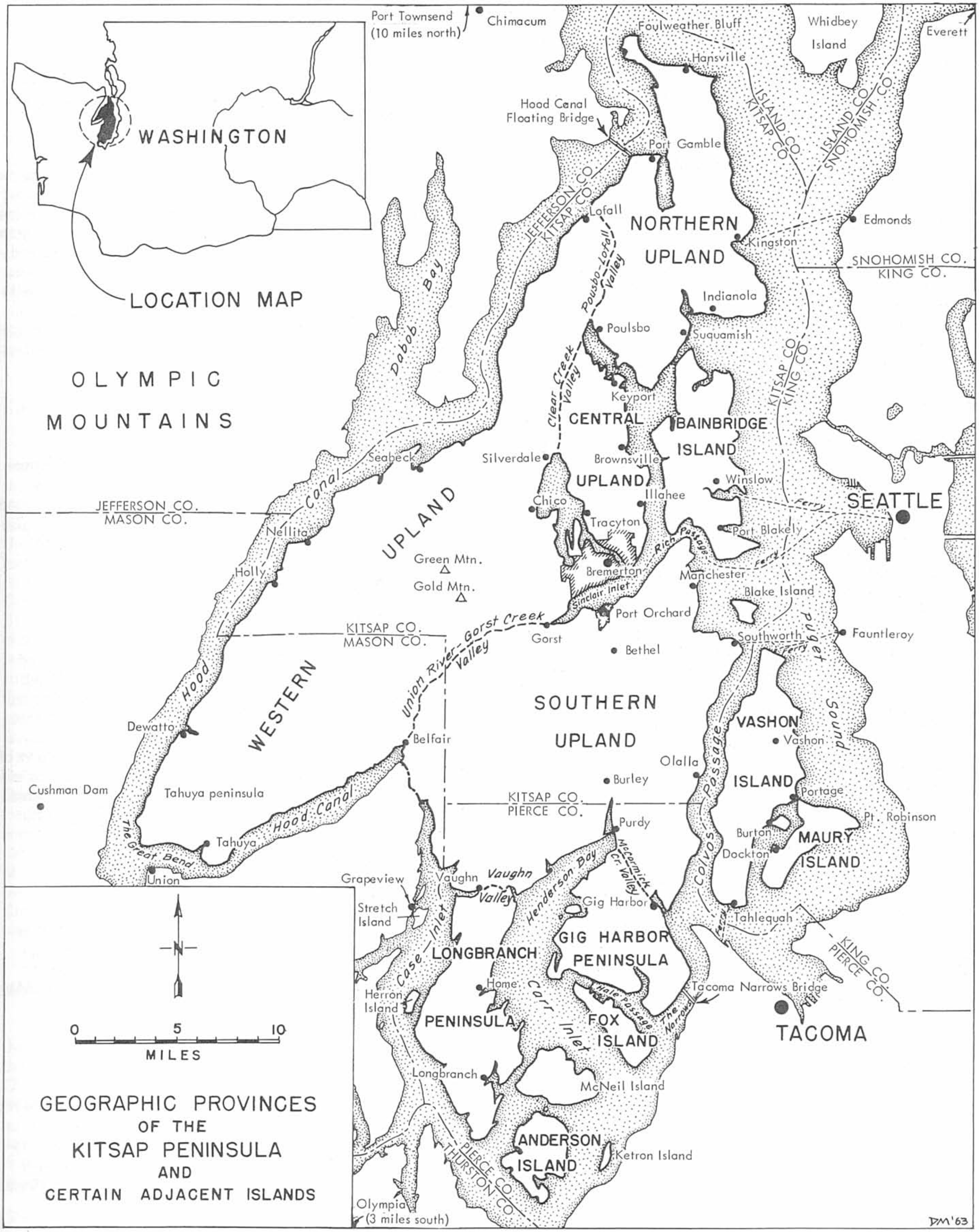

GEOGRAPHIC PROVINCES OF THE KITSAP PENINSULA AND CERTAIN ADJACENT ISLANDS
LOCATION MAP
WASHINGTON
OLYMPIC MOUNTAINS
NORTHERN UPLAND
CENTRAL UPLAND
BAINBRIDGE ISLAND
UPLAND
WESTERN
SOUTHERN UPLAND
VASHON ISLAND
MAURY ISLAND
GIG HARBOR PENINSULA
LONGBRANCH PENINSULA
FOX ISLAND
ANDERSON ISLAND
SEATTLE
TACOMA
Port Townsend (10 miles north)
Chimacum
Foulweather Bluff
Whidbey Island
Everett
Hansville
Hood Canal Floating Bridge
Port Gamble
ISLAND CO.
KITSAP CO.
SNOHOMISH CO.
JEFFERSON CO.
Lofall
Edmonds
Kingston
KING CO.
Pousbo-Lofall Valley
Dabob Bay
Indianola
Poulsbo
Suquamish
Clear Creek Valley
Keyport
Brownsville
Silverdale
Seabeck
Winslow
Canal
Illahee
Chico
Tracyton
Ferry
JEFFERSON CO.
MASON CO.
Nellita
Rich Passage
Port Blakely
Green Mtn.
Bremerton
Manchester
Holly
Gold Mtn.
Sinclair Inlet
Blake Island
Port Orchard
Union River - Gorst Creek Valley
Gorst
Fauntleroy
Southworth
Puget Sound
Bethel
Hood
Dewatto
Belfair
Olalla
Colvos Passage
Vashon
Cushman Dam
Tahuya peninsula
Burley
Portage
Hood Canal
PIERCE CO.
Purdy
Pt. Robinson
The Great Bend
Tahuya
Burton
Dockton
Union
McCormick Cr. Valley
Henderson Bay
Grapeview
Vaughn
Vaughn Valley
Gig Harbor
Stretch Island
Tahlequah
Case Inlet
Hale Passage
Tacoma Narrows Bridge
Home
Carr Inlet
The Narrows
Herron Island
N
0 5 10
MILES
Longbranch
McNeil Island
Ketron Island
THURSTON CO.
Olympia (3 miles south)
DM'63

Figure 1.

CHARACTERISTICS OF THE REGION

PHYSICAL DESCRIPTION

By Dee Molenaar

PHYSIOGRAPHY

Kitsap Peninsula and certain adjacent islands lie entirely within the Puget Trough section of the Pacific Border physiographic province (Fenneman, 1917, p. 95). The Puget Trough is a long northward-trending lowland between the Cascade Mountains on the east and the Olympic Mountains and the Coast Range on the west, and extends from the central part of western Oregon into Canada. Its northern section within the State of Washington contains the marine embayments known collectively as Puget Sound. These embayments occupy a drainage system that has been greatly modified by glaciation.

Most of the land area of the Puget Sound region consists of remnants of a glacial drift plain. The surface is composed generally of low, flat-topped rolling hills and ridges separated by valleys and marine embayments. The land areas generally rise to altitudes of 400 to 600 feet and range in size from small islands of less than a square mile in area to uplands of several hundred square miles. Most of the slopes from the upland areas to Puget Sound are quite steep. Wave cutting at the foot of the slopes has in places produced sea cliffs which are as much as several hundred feet high.

The Green Mountain-Gold Mountain area west of Bremerton is a rugged group of hills which cover about 20 square miles. They are composed of volcanic rocks and, related as outliers to the Olympic Mountains, rise as an "island" above the surrounding plateau surface to a maximum altitude of 1,761 feet. Their individual hills are separated by steep-walled canyons which have been eroded to depths as great as 1,000 feet.

VEGETATION

The original virgin forests that covered the study area a little more than 100 years ago have now been more completely harvested than those of any other area in the Douglas fir region of western Washington and Oregon. This has been due primarily to the accessibility of the peninsular and insular areas to tidewater and to the highly-developed lumber-manufacturing centers of Puget Sound. With such favorable conditions, logging began at an early date and has progressed until only a few small scattered parcels of original stand remain. Only about a third of the remaining saw-timber volume is today composed of old-growth timber.

The virgin timber growth consisted dominantly of Douglas fir, interspersed with western hemlock, spruce, western red cedar, willow, alder, Oregon maple, vine maple, and madrona. Conifers and deciduous trees have reseeded in most of the cut-over or fire-scarred areas and have attained a growth for future utilization. The undergrowth is a luxuriant and dense tangle of many different plants, some of which grow to heights ranging from 4 to 6 feet. It consists mainly of salal, ferns, huckleberry bushes, Oregon grape, rhododendron, vines, and coarse grasses. Fireweed is common over cleared and burned-over areas. Many of the marshy areas are treeless, and the principal growth in such places includes mosses, cranberry bushes, wire grass, reeds, rushes, sedges, ferns, and other water-loving plants. Conifers dominate the forests on the deep sandy soils and deciduous trees are common on soils with a higher water-holding capacity. In the wetter sections, alder grows abundantly, interspersed among the evergreens, and in some such areas second-growth alder is the domiant tree.

GEOGRAPHIC PROVINCES

In this report the area has been divided into nine geographic provinces as shown on Figure 1. These provinces include the northern upland, central upland, Bainbridge Island, western upland, southern upland, Vashon-Maury Islands, Gig Harbor peninsula-Fox Island, Longbranch peninsula, and Anderson Island.

NORTHERN UPLAND

The northern upland is bounded on the west by Hood Canal and the Poulsbo-Lofall valley, on the east by Puget Sound proper, and on the south by Liberty Bay, Port Orchard and Port Madison. The maximum altitude is about 520 feet but most of the land area ranges from 200 to 400 feet above sea level. The province is separated from the northern part of the western upland by a narrow drainage channel which extends from Liberty Bay at Poulsbo to Lofall. The upland is drained by short streams that discharge into the surrounding marine waters.

CENTRAL UPLAND

The central upland comprises the Manette peninsula and is separated from the western upland by the southwest-trending Clear Creek valley. The upland has a maximum altitude of about 480 feet. Drainage of the province is similar to that of the northern upland.

BAINBRIDGE ISLAND

Bainbridge Island (27.6 square miles) is a roughly rectangular island. Its highest point, east of Fort Ward, has an altitude of 425 feet and the altitude of most of the island is 200 to 300 feet above sea level. As with the central and northern uplands drainage is by small, short spring-fed streams that discharge into the Puget Sound.

WESTERN UPLAND

The western upland includes the entire western part of Kitsap County and the Tahuya peninsula part of Mason County. Excluding the Green Mountain-Gold Mountain hills,the altitude of the surface is generally from 300 to 600 feet above sea level. Drainage of the southern part of the upland is primarily by the Tahuya and Union Rivers and Mission and Dewatto Creeks, while the northern and eastern areas are drained primarily by Big Beef Creek and Wildcat Creek. Numerous short streams also drain the peripheries of the upland along Hood Canal. Most of these streams occupy steep, narrow canyons and gullies. Numerous small lakes occupy depressions in the southern part of the western upland. The western upland is separated from the southern upland by the former glacial-outwash channel which is now occupied by Union River and Gorst Creek, from the central upland by the Clear Creek valley and from the northern upland by the Poulsbo-Lofall valley.

SOUTHERN UPLAND

The southern upland is a large, irregular-shaped rolling area that occupies the south part of Kitsap County and includes the northwestern peninsular part of Pierce County and a narrow strip along the northeastern edge of Mason County. It is bounded on the north by Sinclair Inlet, on the west by the Union River-Gorst Creek valley and North Bay of Case Inlet, on the east by Puget Sound proper and Colvos Passage, and on the south by Vaughn valley, Henderson Bay and McCormick Creek valley. Its surface generally ranges in altitude from 300 to 450 feet, but rises to a maximum of 525 feet. Its chief land forms are broad flat-topped hills and ridges. Included in the southern upland is Blake Island (0.78 square mile) which lies in Puget Sound north of Harper.

The area is drained by many small creeks and several large streams, chief among these being Blackjack Creek and Curley Creek which drain northward to Sinclair Inlet and Yukon Harbor, respectively, Olalla Creek which drains eastward to Colvos Passage, Minter Creek, Burley Creek and Crescent Creek which drain southward into Henderson Bay and Gig Harbor, and Coulter Creek and Rocky Creek which drain westward into North Bay. The southern upland also contains several lakes and numerous ponds. The largest, Long Lake, at the head of Curley Creek, lies in the east-central part of the upland close to the divide between Curley Creek and Olalla Creek. Many smaller lakes and ponds are located in the western part of the province.

VASHON-MAURY ISLANDS

Vashon Island (29.7 square miles) is separated from the southern upland on the west by Colvos Passage and from the mainland on the east by Puget Sound proper. Maury Island (7.04 square miles) is joined to the east side of Vashon Island by a narrow isthmus at the community of Portage near the head of Quartermaster Harbor. These two islands are the only part of the report area that lies within King County. Both islands are drained by small streams which flow into the surrounding marine waters.

GIG HARBOR PENINSULA-FOX ISLAND

The Gig Harbor peninsula includes that part of Pierce County extending southward from the southern upland between Carr Inlet on the west and the Tacoma Narrows on the east. In this report the peninsula is defined as being separated from the southern upland by the McCormick Creek valley north of Gig Harbor. Fox Island (5.08 square miles), lying off the south end of the Gig Harbor peninsula, and reached by bridge across Hale Passage, is included in the discussion of the peninsula.

The Gig Harbor peninsula is drained by many small streams that flow into the surrounding marine waters, the largest being Artondale Creek which drains southward from the central part of the peninsula into Wollochet Bay. Fox Island is characterized by relatively gentle north slopes and generally precipitous sea cliffs along its southern and eastern margins.

LONGBRANCH PENINSULA

The Longbranch peninsula is that part of Pierce County lying south of Vaughn valley and extending southward from the southern upland. The 12-mile long area is bounded on the west by Case Inlet and on the east by Carr Inlet. Herron Island, one mile long and a half-mile wide, lies offshore in Case Inlet and is included with this area.

The Longbranch peninsula is drained by short streams and springs that issue from its relatively steep slopes, and longer streams that drain the uplands where deeper valleys head several embayments along the shoreline.

ANDERSON ISLAND

Anderson Island (8.10 square miles), in Pierce County, is the most southerly of the areas studied for this report. The island is located in Puget Sound one and a half miles southeast of the southern end of Longbranch peninsula. The island is characterized by relatively gentle north-facing slopes and steep southern and eastern sea cliffs. The island has a maximum elevation of approximately 280 feet above sea level. Two natural lakes, Lake Florence and Josephine Lake, occupy connected depressions on the northeastern part of the island. Drainage from the island is primarily by short streams and springs. The largest streams are the two which flow into the heads of Ora Bay and East Ora Bay.

McNEIL ISLAND-KETRON ISLAND

McNeil Island (6.77 square miles) lies in Puget Sound north of Anderson Island and east of Longbranch peninsula. Because it is administered as a Federal penitentiary by the Department of Justice, and development of the water resources of the Island has been limited almost entirely to penitentiary needs, this report includes only the surface-water drainage characteristics and the existing reservoirs of the Island.

Ketron Island (0.36 square mile) lies off the Pierce County mainland east of Anderson Island. As the geology and ground-water resources of the island are included in the Pierce County report by K. L. Walters and G. E. Kimmel (in preparation), only the surface-water drainage characteristics are included in this present study.

CLIMATE

By M. E. Garling

GENERAL CIRCULATION PATTERN

The Kitsap Peninsula has a characteristically maritime climate, typified by relatively short, cool, dry summers and prolonged, mild, wet winters. Essentially, this seasonal variation results from changes in the general location of two major air masses. In the northern hemisphere, an atmospheric high-pressure area tends to persist over the northeastern part of the Pacific Ocean, while farther north, in the Gulf of Alaska, atmospheric circulation is conducive to the development of low-pressure cells. It is this major low-pressure center that generates most of the storms experienced along the west coast of North America.

In summer the "Pacific High" extends to higher latitudes as the northern hemisphere is exposed to more direct insolation and the region of low pressure and storm activity is pushed northward. As winter approaches the reverse action occurs. The low-pressure region extends southward as the "Pacific High" recedes, resulting in the occurrence of a progressively increasing number of storms at lower latitudes. These storms are commonly widespread and have paths that are often several hundred miles in width.

The flow of moisture-laden air which accompanies winter storms usually approaches the Pacific Coast of Washington from the southwest. When these storm cells reach the coast, the air-flow, depending upon location, is either (1) retarded in its movement and forced to over-ride the Olympic Mountains, Black Hills and Willapa Hills, or (2) it is funneled inland through gaps between these uplands. In the former case, where orographic features cause the air masses to rise, much of the atmospheric moisture is precipitated onto the windward slopes of the uplands causing a decided rain shadow to form on the lee side. In the latter case, where saturated air moves through the low passes, precipitation occurs at a slower rate and is more uniformly distributed along the storm path.

Climate in the report area is affected by both of these actions. In winter, the southwestern part of the Kitsap Peninsula is generally well watered because it is primarily influenced by air flow through the gap between the Olympic Mountains and Black Hills. The northern extremity of the peninsula, however, projects well into the Olympic Mountain rain shadow and enjoys much drier winter weather. In the central part of the peninsula, winter climate varies between that of the above two extremes. During summer, weather over the entire report area is dominated by the "Pacific High" and few major storm disturbances penetrate into the Puget Sound area. Precipitation during this period is generally limited to isolated shower activity, and clear sunny days usually prevail. Late spring and early fall are transitional periods between the wet and dry seasons, but the change is not well defined in the northern part of the report area.

AVAILABLE BASIC DATA

Climatological data used in the following analysis were obtained from 5 stations within the report area and 39 stations located around the area and along the Pacific Coasts of Oregon, Washington and British Columbia.

Of those located within the report area, the Bremerton station exhibits the longest precipitation and temperature record. Data have been collected here since 1899, although a short gap occurs in the record from 1906-08. Because the gage has occupied four different locations in Bremerton during its history, the record is unreliable for use in establishing long-term trends.

The station at Madrone near Winslow on Bainbridge Island has about 21 years of precipitation and temperature record but, because these data were obtained during the period 1878 to 1899, they were of only limited value in the study.

Precipitation quantities and temperature were recorded at an unknown location in Poulsbo from 1915-21. The instruments used there were then transferred to the U.S. Navy Torpedo Station at Keyport where a sporadic record was established during the period 1921-53.

Measurements of precipitation and temperature were made on Vashon Island from 1887 to 1955, but the station location was changed seven times during this period and the record exhibits many gaps.

Because available data within the report area were generally inadequate to properly evaluate the areal distribution of precipitation, records from several nearby stations were also employed in the analysis. The most useful information was provided by the Grapeview station. This station, located on Stretch Island in Case Inlet (8 miles south of Belfair and 4 miles west of Vaughn), has been maintained primarily by one observer and provides a record with only minor interruptions at a single location dating back to 1907. The record was considered to be one of the more reliable sources of hydrologic information in the lower Puget Sound area and is employed in many subsequent investigations in the report.

Precipitation and temperature data collected at Port Townsend were most useful in establishing climatic trends near the northern part of the report area. Observations have been made here since 1857 and the records generally can be classified as good, though the station occupied two different locations during its history.

Excellent information for delineating climatic trends along the eastern boundary of the report area was provided by three U.S. Weather Bureau stations in the Seattle area. These stations, located in downtown Seattle, at Boeing-Field Airport and at Seattle-Tacoma Airport, observe several types of meteorological phenomena and their records are generally of high quality and display few interruptions. The Weather Bureau station at Olympia was also close enough to the report area to be of some value.

Other climatic stations in the Puget Sound area useful in evaluating the areal distribution of precipitation were located at Port Angeles, Sequim, Coupeville, Arlington, Chimacum, Everett, Quilcene, Quilcene Dam, Bothel, Maple Leaf Reservoir in Seattle, Cushman Dam, Union, Wauna, Kent, Shelton, Tacoma, Puyallup and Auburn. Streamflow data (p. 56) were also valuable in estimating precipitation quantities, especially in areas where no climatic data were available.

PERIOD OF STUDY

The two basic standard periods of study to be used in most statistical hydrologic analyses in all inventory reports were established through investigations conducted at the beginning of the water resource inventory program. At that time, an examination of available data in the State of Washington revealed that climatological data were recorded at many locations prior to 1900 but most streamflow records were obtained since 1930. Though the reliability of an analysis is generally improved by incorporating as much data as possible, in order to permit valid comparisons, it is also necessary to derive statistics from a common period of record. To comply with the later requirement, most hydrologic studies would have to be restricted to the use of data obtained during the past three to four decades.

Long-term records indicated that past climatic variations generally followed the same trend, throughout the state. This similarity further justified the use of common periods of study in all reports.

In selecting a period of study, it is also important to consider the effects of storage. Discrepancies can be introduced if a difference exists between the beginning and end of the period in the amount of ground water and surface water held in storage. In dry periods, it is difficult to assess how much water is retained in storage, but the amount essentially reaches a maximum when the potential storage capacity of an area approaches complete utilization during extremely wet periods. Thus, to reduce the possibility of introducing such discrepencies, it is desirable to choose a specific period of study which both begins and ends with a year of high precipitation.

In most hydrologic investigations it is convenient to use a standard annual period of study called the water-year. Beginning with the month of October and ending the following September, the water-year in most areas is least affected by antecedent conditions and lag.

With the foregoing limitations and criteria in mind, it was reasoned that the 26 water-years of 1934 through 1959 presented a desirable period of study throughout most of the state. Weather during the 1934 water-year was generally quite wet throughout western Washington, while in eastern Washington, precipitation quantities at most stations ranked a little above normal. Similar conditions prevailed during the 1959 water-year.

To permit comparisons, it was decided that trends during the 26 years preceeding the above period would also be investigated. A cursory examination of precipitation records for several long-term stations indicated average climatic conditions in the state were quite similar during these two periods.

In analyzing hydrologic conditions in the Kitsap report area, certain investigations were based on the above outlined 26-year periods. However, in areas such as this, where available basic data are generally of short duration, the validity of analyses representing conditions during these 26-year periods is somewhat questionable. It was, therefore, decided that shorter periods of study, conforming more to the length of available record, would also be used.

Because one of the main purposes of a water resource inventory is to evaluate usable sources of supply, available streamflow records in the report area, rather than climatic records, became the prime factor in establishing the length of the shorter period of study. Continuous record streamflow data were not recorded in the Kitsap Peninsular area prior to 1945 (see p. 60), consequently the 15 water-years of 1946 through 1960 were chosen for a short-term period of study in this report.

GENERAL CLIMATIC TRENDS

The long-term precipitation records of Port Townsend and Grapeview were selected to show differences in climatic trends between the northern and southern parts of the report area. As previously described, these records exhibit only minor interruptions and, although the Port Townsend gage occupied two different locations during its history, neither station has been moved since 1907.

Annual water-year precipitation at these stations for the period 1908-62 is shown in figure 2. The amounts of precipitation measured in each of these years during the months of October through April and May through September are also plotted for comparison. Averages for the 3 plots over the 55-year period are indicated along the right margin of figure 2. These averages are expressed in terms of inches of precipitation and the percentages that the Oct.-April and May-Sept. averages are of the mean annual water-year precipitation.

In general, quite similar trends occurred at both stations, though the mean annual precipitation at Grapeview during this period was about three times as great as that at Port Townsend. To show the similarity of trends more clearly, 10-year moving-average curves are superimposed on the above plots. These curves were established by first computing mean values for consecutive 10-year periods and then plotting the values at the midpoint of each 10-year period.

The resulting curves show that such 10-year average precipitation was lower than normal at both stations during the late 1920's and again in the early 1940's but at the Grapeview station the tendency was decidedly more pronounced during the later period. The same trends appeared in the Oct.-April and May-Sept. decadal average precipitation with the exception of the early 1940 period at Port Townsend which was about normal. In addition, the 10-year average May-Sept. precipitation during the mid 1950's tended to be slightly lower than normal at both stations. The water-year and Oct.-April curves are in close agreement during the intervening wetter-than-normal decadal periods, but the May-Sept. curves show only slight similarity to the others during these times.

Mean annual water-year precipitation at the Grapeview station during the 1908-33 period was nearly the same as that received during the more recent 26-year period, 1934-59. A significant difference, however, was found between the means for these periods at the Port Townsend station. Precipitation at Grapeview during the earlier period was lower than that of the later period by an average of 0.21 inch per year or about 0.4 percent. At Port Townsend, the earlier period also produced a lower average but the difference was greater to the extent of 0.93 inch per year or about 5.1 percent.

Precipitation averages for the shorter 1946-60 period were considerably higher than those of either long-term period. A comparison between this 15-year period and the 1934-59 period showed a difference of 2.16 inches per year or 4.2 percent at Grapeview and 0.98 inch per year or 5.4 percent at Port Townsend. (All percentages are based on 1934-59 values.)

Listed in column 4 of table 1 are values of mean annual precipitation at the two stations for seven different periods of record, including the three standard periods mentioned above. Each mean value, derived from a given sample of record, represents an estimate of the all-time or population mean at that location. (Population, as used in this sense, refers to all possible values of a variable.)

Confidence limits for the population mean, based on the data for each period and computed at a probability level of 0.95, are shown in column 5. Each expression in this column states that there is a probability of 0.95 that the computed interval will contain the population mean. For example, the first expression, $P(49.72 < u < 58.50) = 0.95$, indicates that there is a probability (P) of 0.95 that the interval from 49.72 inches to 58.50 inches, derived from data for the period 1946-60, will contain the all-time mean annual

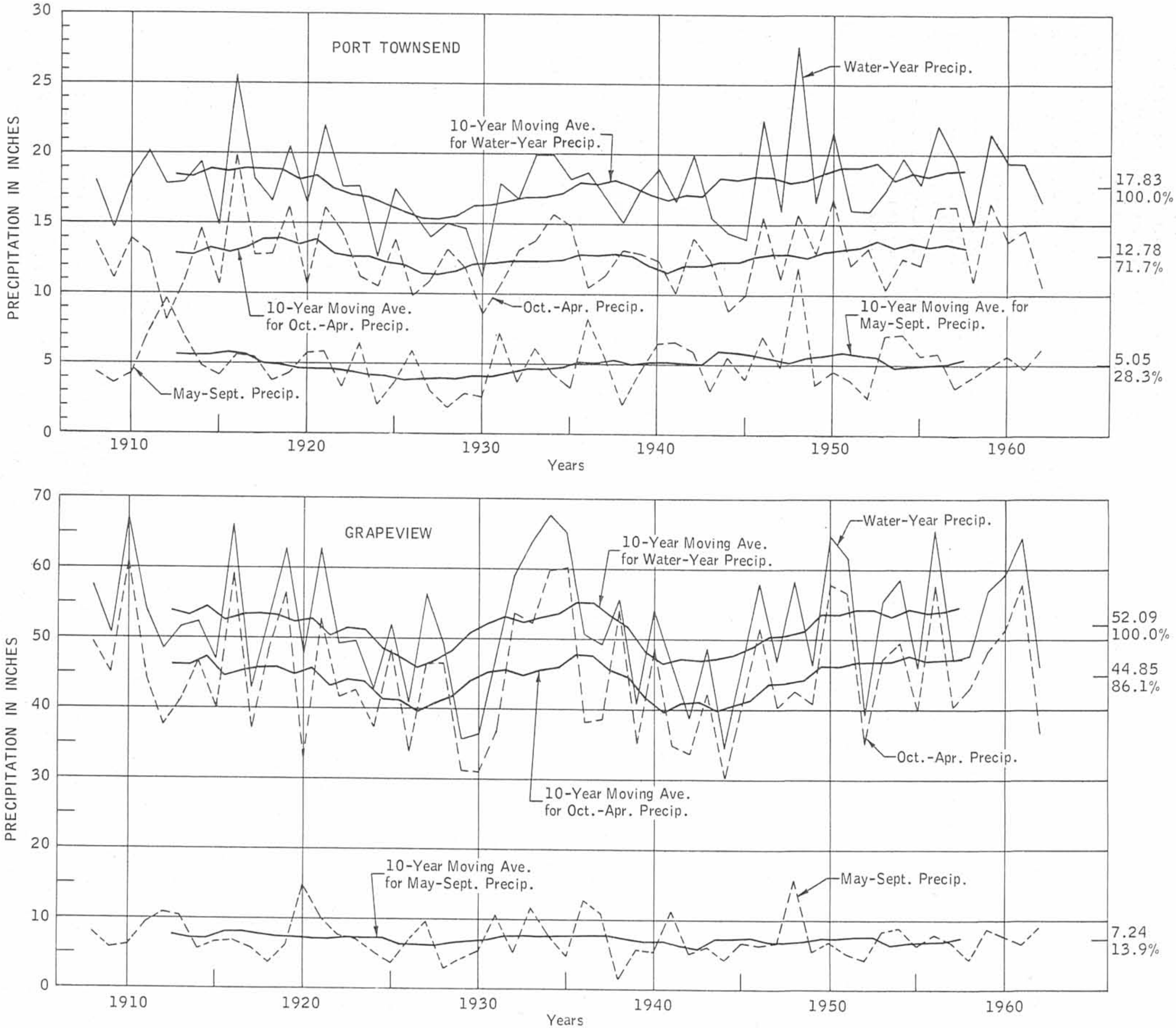


Figure 2. WATER-YEAR, OCTOBER-APRIL AND MAY-SEPTEMBER PRECIPITATION AT PORT TOWNSEND AND GRAPEVIEW STATIONS.

Table 1. STATISTICS SHOWING THE VARIATION OF WATER-YEAR PRECIPITATION.

Station Location	Period of Analysis No. of Years	Period of Analysis Dates	$\bar{X}$ Mean for Period Inches	Confidence Limits for Population Mean, u Inches	S Standard Deviation Inches	3S Three St'd. Deviations Inches	PE Probable Error Inches	CV Coeff. of Variation %
Grapeview	15	46-60	54.11	$P(49.72<u<58.50) = 0.95$	7.93	23.78	5.35	14.65
	26	08-33	51.74	$P(48.30<u<55.18) = 0.95$	8.51	25.54	5.74	16.45
	26	34-59	51.95	$P(48.32<u<55.58) = 0.95$	8.99	26.98	6.07	17.31
	52	08-59	51.84	$P(49.43<u<54.25) = 0.95$	8.67	26.01	5.85	16.73
	53	08-60	51.98	$P(49.60<u<54.36) = 0.95$	8.64	25.94	5.83	16.63
	55	08-62	52.09	$P(49.74<u<54.44) = 0.95$	8.69	26.07	5.86	16.68
	50	10-59	51.75	$P(49.25<u<54.25) = 0.95$	8.81	26.42	5.94	17.02
Port Townsend	15	46-60	19.24	$P(17.36<u<21.12) = 0.95$	3.40	10.21	2.30	17.68
	26	08-33	17.33	$P(16.13<u<18.53) = 0.95$	2.97	8.91	2.00	17.14
	26	34-59	18.26	$P(17.01<u<19.51) = 0.95$	3.08	9.26	2.08	16.90
	52	08-59	17.79	$P(16.95<u<18.63) = 0.95$	3.04	9.10	2.05	17.06
	53	08-60	17.82	$P(16.99<u<18.65) = 0.95$	3.01	9.04	2.03	16.91
	55	08-62	17.83	$P(17.03<u<18.63) = 0.95$	2.97	8.90	2.00	16.65
	50	10-59	17.85	$P(16.98<u<18.72) = 0.95$	3.06	9.19	2.07	17.16

precipitation (u) at Grapeview. The reliability of each sample mean as an estimator of the population mean is implied by the relative range of the confidence interval. In general, the reliability increases as the confidence interval for the population mean decreases.

Frequency distributions of water-year precipitation for the Grapeview and Port Townsend stations were found to be slightly skewed to the right. That is, for the water-years 1908-62, annual precipitation was below normal more often than it was above normal. At both stations below normal precipitation occurred during 30 of the 55 years; consequently, annual wet-year precipitation was somewhat more variable or extreme than annual dry-year precipitation.

The standard deviation from the mean and other associated statistics, listed in columns 6-9 of table 1 were computed for several different periods to show the amount of precipitation variability at each station. These statistics are based on the assumption that the annual precipitation at each station occurs in a normal frequency distribution. The actual distributions, as indicated above, are somewhat skewed, but for practical purposes the normal frequency distribution is a close approximation. The application of a common distribution is also desirable as it provides a standard set of statistics which can be easily compared. If the normal distribution is valid, 68 percent of all deviations both greater and less than the mean annual precipitation may be expected to fall within the limits described by the standard deviation from the mean. Conversely, in 16 percent of all cases the annual precipitation may be expected to be less than the value expressed by the mean minus one standard deviation and 16 percent of the cases may be expected to be greater than the quantity established by the mean plus one standard deviation. The values denoted by the mean plus three standard deviations and the mean minus three standard deviations indicate the range in which 99.7 percent of all the individual annual quantities of precipitation may be expected to occur. This may be interpreted as the limiting variability range for all values of annual precipitation almost without exception. The probable error, which is equal to 67.45 percent of the standard deviation, is defined as the amount of deviation from the mean that is just as likely to be exceeded as not. The coefficient of variation expresses the standard deviation in terms of a percentage of the mean.

The standard deviation from the mean for the selected periods ranged from 7.9 to 9.0 inches at Grapeview and 3.0 to 3.4 inches at Port Townsend. Though the magnitudes of these deviation statistics differ considerably between the two stations, the percentagewise variations, expressed by the coefficients of variation, are nearly identical. With the exception of the 1946-60 period at Grapeview, the coefficients of variation for both stations were all grouped between 16.5 percent and 17.6 percent. This similarity and the comparatively low value of the coefficients indicate that the entire report area is generally influenced by the same climatic regimen and the type of climate is quite consistant from year to year.

PRECIPITATION

The areal pattern of precipitation in western Washington shows an extensive rain shadow in the lee of the Olympic Mountains. This phenomenon is barely noticeable in the lower part of Puget Sound, but to the north it intensifies, becoming most pronounced in the vicinity of Port Townsend. As a result, the northern extremity of the Kitsap Peninsula near Hansville generally experiences the lowest annual precipitation in the report area. At this location precipitation was estimated to average about 26 inches per year during the water-years, 1946-60.

An anomalous precipitation high occurs in the area of Green and Gold Mountains. Though these low mountains exhibit only moderate relief, the orographic influence is sufficient to increase precipitation by about 30 percent more than that in the surrounding area. Actual precipitation data were lacking but streamflow measurements in this area indicated a mean annual precipitation near the summits in excess of 80 inches.

With the exception of this low mountainous area, annual precipitation in the northern part of the report area gradually increases in a southwesterly direction. In the southern part there is a general increase from east to west with a maximum of about 70 inches in the southwestern part of the Western Upland. The complete areal pattern of mean annual precipitation is depicted on plate 4 in the form of an isohyetal map. The "isohyets," or lines of equal precipitation, are shown in blue and were developed from data obtained during the period 1946-60.

Existing precipitation sampling points in the report area were inadequate to establish a direct relationship between precipitation and elevation, but an analysis of streamflow data indicated that such a relationship does exist. Correlations of median basin elevation with mean annual runoff for the periods 1934-59 and 1946-60 produced identical correlation coefficients of 0.81. (A correlation coefficient of 1 represents a perfect correlation and no correlation is indicated by a coefficient of 0.)

Figure 3 shows by bar charts the mean monthly distribution of precipitation at various stations in and around the report area. All of these charts show a winter maximum and summer minimum but, percentagewise, winter precipitation is decidedly greater at the more southerly stations. The same tendency is indicated in figure 2. As shown along the right margin, the average Oct.-April contribution at Grapeview was 86.1 percent of the mean annual quantity whereas, at Port Townsend, the amount received during like periods was only 71.7 percent of the total.

The bar charts for most of the stations define a rather smooth cyclic seasonal pattern with the occurrence of a primary maximum usually during the months of December or January and a minimum, in all cases, in July. Although not always obvious, a secondary maximum also occurs in the month of June. The increase is most apparent at the stations of low annual precipitation lying in the Olympic Mountain rain shadow whereas, at the stations of higher annual precipitation, the effect is only slightly noticeable.

Precipitation in the form of snow occassionally occurs at higher elevations in the report area during the winter months, but predominantly mild temperatures produce rapid melting and the storage effect is insignificant.

TEMPERATURE

Temperatures in the report area clearly reflect the moderating influence of Puget Sound waters and the Pacific Ocean. Only brief periods of sub-freezing weather occur in winter, and in summer, mean temperatures during the hottest months seldom exceed 70°F.

Typical trends are shown by the bar graphs of mean monthly temperature at Port Townsend and Grapeview (fig. 4). To illustrate normal variations, mean minimum and mean maximum monthly temperatures are also indicated. At both stations, the coldest mean monthly temperatures occur in the month of January and the maximum mean monthly temperatures occur in either July or August. The January temperatures are nearly identical at both stations but temperatures in July and August average about four degrees higher at Grapeview.

The range between mean minimum and mean maximum temperatures is about the same at both stations in winter, but toward summer this range increases and reaches a maximum in the months of July and August. Though both stations display this same general trend, at Grapeview the range between maximum and minimum increases at a faster rate and is significantly greater in the warmest months.

The highest temperature on record at Grapeview was 102°F. and occurred in both June and July. The minimum recorded temperature of 8°F. occurred in the months of January and February.

At Port Townsend the extremes were a few degrees lower. The maximum temperature at this station of 96°F. occurred in August, and the minimum of -3°F. occurred in January. In comparison, this range of 99°F. was only 4°F. greater than the range at Grapeview.

Though Port Townsend exhibits the lowest minimum temperature, the growing season at this station is normally somewhat longer than at Grapeview. Port Townsend has an average freeze-free period of 258 days per year, whereas Grapeview averages only 224 consecutive days with above freezing temperatures per year. Extremely cold temperatures in the Puget Sound area are usually caused by outbreaks of cold polar air from central British Columbia. Most of the lighter frosts, however, result from radiational cooling on calm clear nights.

WATER BUDGET

The term "water budget", as used in this report, can be defined as a quantitative accounting of various interrelated phases of the hydrologic cycle as they vary with time. Available data do not permit such an accounting for the entire report area; however, a general picture can be obtained by studying hydrologic relationships at the Grapeview and Port Townsend stations.

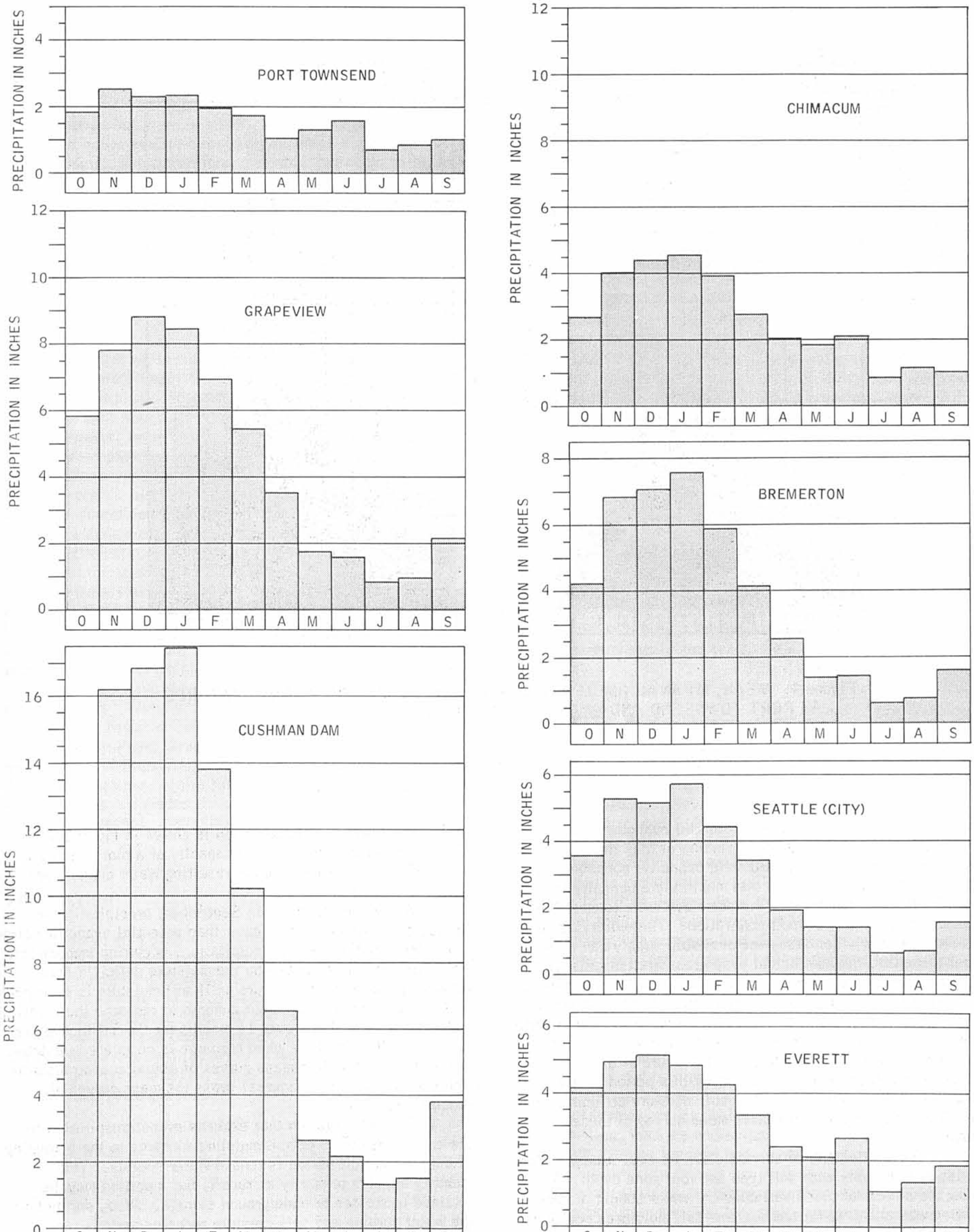
These relationships are graphically shown in figures 5, 6, 7 and 8. Curves in the upper part of each figure show the mean daily procession of precipitation and evapotranspiration and how these quantities are associated with soil moisture and runoff. Ordinates to these curves represent inches of water per day. The lower group of curves in each figure represent cumulative or mass totals of the quantities described by the upper curves. All of the curves have time in days as their abscissa, though only the monthly divisions are shown.

As previously discussed, the curves of mean daily precipitation for both stations show the characteristic pattern of a primary winter maximum followed by a secondary rise in June and a summer minimum. At Port Townsend, however, the secondary June rise is nearly as great as the subdued winter maximum.

Evapotranspriation quantities, which include both direct evaporation from water surfaces and transpiration from plant life, were computed by the Thornthwaite procedure (Thornthwaite, 1957; Wash. Div. Water Resources, 1960, p. 15). This method is based on an empirical relationship between temperature and latitude, and utilizes only conventional climatological data. Because evapotranspiration is mainly dependent on available insolation, it is potentially greatest in mid-summer and varies in direct opposition to the trend of precipitation.

At Grapeview, January precipitation is approximately 14 times greater than the concurrent potential evapotranspiration. During the following months, however, this difference rapidly diminishes and the two quantities become equal near the end of April. In the mass curve analysis, the time of equality is established when the slopes of the cumulative curves are identical. This time can also be found by locating the point of tangency (1) between the shifted mass curve of potential evapotranspiration (curve AB) and the mass curve of precipitation.

Figure 3. MEAN MONTHLY PRECIPITATION AT VARIOUS STATIONS FOR THE PERIOD 1946-60*



*See figure 1 for station locations

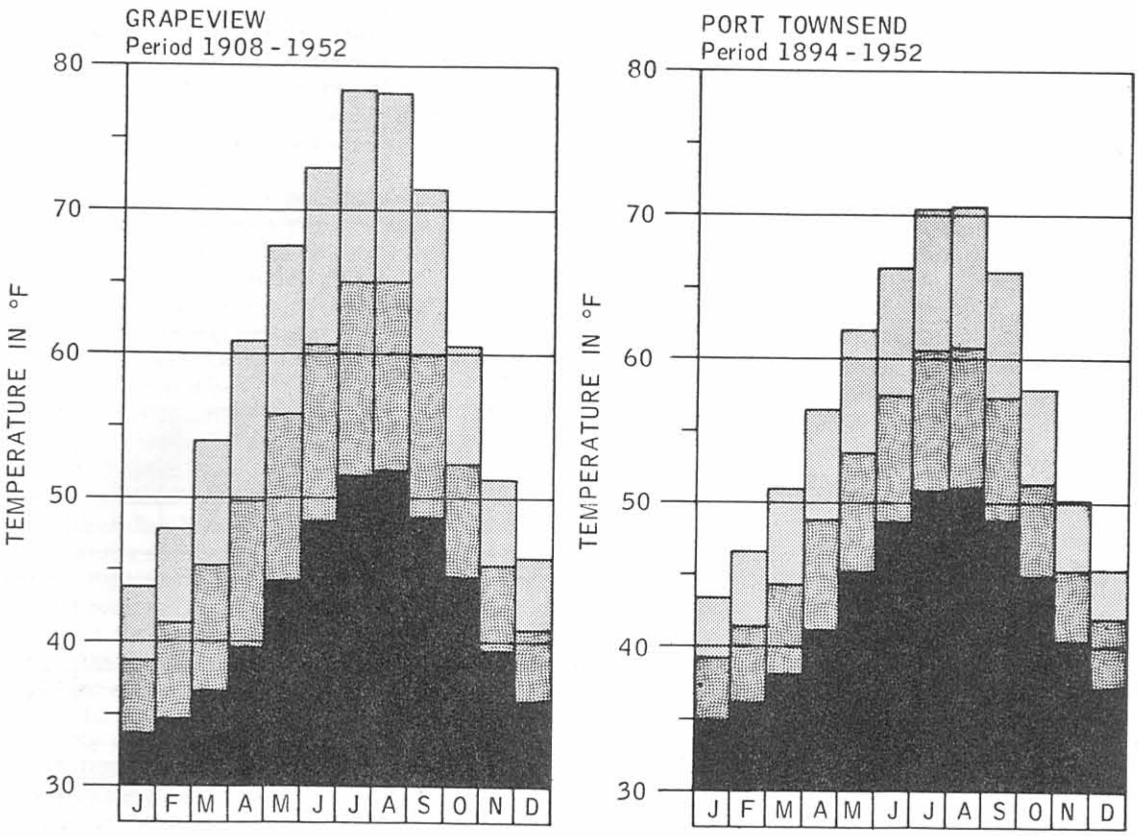


Figure 4. MEAN, MEAN MINIMUM AND MEAN MAXIMUM MONTHLY TEMPERATURES AT PORT TOWNSEND AND GRAPEVIEW STATIONS.

Throughout the summer, potential evapotranspiration exceeds precipitation. At the beginning of May the soil is essentially saturated to its full field capacity; consequently, during the first week or so in this month there normally is enough precipitation and soil moisture available to meet the demands of potential evapotranspiration. Thereafter, as soil moisture is slowly depleted, the available supply can no longer meet these demands and actual evapotranspiration falls well below the potential. During this time a so-called water deficit is said to exist. The extent of this deficit is represented by the difference between the actual and potential evapotranspiration curves. The difference between the precipitation and actual evapotranspiration curves is a measure of the soil moisture depletion or utilization during this period. At any time the total amount of deficit or soil moisture utilization can be determined from the respective mass curves of these quantities.

The availability of soil moisture for evapotranspiration varies considerably with soil type and root zone depth. To show the effects of these variables the water budget at each station was analyzed for two extreme soil moisture conditions. The type of soils and vegetation indicated that 10 inches of water would be about the maximum capacity of any root zone in the report area. This condition is shown in figures 5 and 7. The minimum water holding capacity of a root zone was assumed to be 2 inches and the resulting water budgets are shown in figures 6 and 8.

About the last week in September, precipitation at Grapeview again becomes greater than potential evapotranspiration. Most of the excess precipitation, occurring immediately after this time, is absorbed by the moisture deficient soil. Assuming that no runoff occurs until soil moisture is completely replenished, it will take about a month to recharge the 2 inch water capacity soil and over 1½ months for the 10 inch water capacity soil. The time when recharge is complete is established when the shifted mass curves of actual evapotranspiration (curves AC on all figures) cross the mass curves of precipitation at (2).

The precipitation that exceeds evapotranspiration from the end of the period of soil moisture recharge to the beginning of the next deficit period is termed water surplus. This quantity appears primarily as runoff, but a portion may be retained in surface or underground storage. Also, during both the water surplus and soil moisture recharge periods, actual evapotranspiration is essentially equivalent to the potential.

Since mean temperatures are quite uniform throughout the report area, the potential evapotranspiration curve for Port Townsend is nearly identical to that of Grapeview; consequently, Port Townsend experiences a shorter water surplus period and a longer deficit period.

Soils with a root zone capacity of 2 inches at Port Townsend can normally be fully recharged during the water surplus period but there is insufficient excess precipitation during the entire year to completely recharge a 10-inch water capacity soil. It is, therefore, possible that some soils in this area might never reach their field-moisture capacity.

ECONOMICS OF THE REGION

By Dee Molenaar and M. E. Garling

HISTORY

The first white man to visit Kitsap Peninsula was the English explorer, Capt. George Vancouver, who in 1792 discovered, explored, mapped, and named many of the embayments of Puget Sound. Settlement of the territory was not made, however, until about a half-century later. Until about 1850, when pioneers began to take up homesteads, the only white persons were transient explorers and fur traders, and the Indians were the only residents. Early white settlements were along the shorelines of the peninsula and islands while the interior uplands were only sparsely settled. A number of small settlements and villages were established and platted throughout the area between 1850 and 1870. Most early settlers, mainly of Scandinavian, German, and English descent, came from the Eastern and Midwestern States. Following World War I the population was augmented to some extent by immigrants from northern Europe. At present, the farming population consists mainly of descendents of the early settlers and people who have recently established themselves in the rural sections. World War II brought on considerable growth of the area as a result of servicemen from other parts of the country settling in the Puget Sound region along with the continued development of Bremerton as "home of the Pacific Fleet." Today, the economy of the Kitsap Peninsula is based primarily upon services and trades associated with the Bremerton Naval Base and Shipyard, and to a lesser extent on forest products and agriculture.

POPULATION

Based on 1962 census figures, it is estimated that the study area has a population of about 105,000. This amounts to a population density of approximately 157 persons per square mile. This is more than 3.6 times the state-wide average of 43 persons per square mile. Of the total, more than 86,000 people live in Kitsap County proper, most of these residing in the Bremerton metropolitan area. Five incorporated cities exist in the report area, all but Bremerton having populations of less than 4000 persons.

INCORPORATED CITIES AND TOWNS

Bremerton

About 1890 the U.S. Navy Department began a search for a suitable site to establish a naval shipyard on the Pacific Coast. After a congressional commission recommended the Port Orchard Bay area, Congress approved the location and appropriated $5000 to acquire land along the north shore of Sinclair Inlet. Here, near the platted town of Bremerton, the Naval Base was established in 1891 and construction was started on the first drydock, a 750-foot long wooden structure.

As operations expanded and employment grew, the town rapidly spread around the base and in 1901 Bremerton was incorporated. Beginning with the Spanish-American War, each major conflict produced an upsurge in Navy Yard employment and a corresponding growth in Bremerton's population until today about 37,000 of Kitsap County's 86,000 people live in this city and approximately another 30,000 reside in the surrounding metropolitan area. Although there have been periods of economic decline between major wars, Bremerton has enjoyed a constant growth and today it ranks as the sixth largest city in the State. The municipality has a complete school system, including Olympic College, which serves the peninsular area. Bremerton also maintains a library, daily newspaper, radio station, and two hospitals.

Except for a rock quarry, sand and gravel mining operations, and some lumbering activity, Navy Yard work completely dominates the area's industrial economy. Nearly all commercial services, trades and local agriculture have been developed in support of the Navy Yard and its large employment. Recent addition of new facilities at the Navy Yard, including the largest drydock in the world, should have a noticeable effect on the economic growth of the region.

Business statistics show that the average household income for Bremerton is about $6200 per year or about $1900 per capita per year.

Bremerton's central location and high population concentration have caused the city to become the main center of commerce for the Kitsap Peninsula. The Peninsula's major highways pass through Bremerton and water transportation to Seattle is provided by the Washington State Ferry System.

Port Orchard

In 1885 Sidney Stevens came to the Puget Sound region from Illinois and settled along the south shore of Sinclair Inlet. There he purchased and subdivided land and established the townsite of Sidney. Several lumber mills began operating in the vicinity and soon Sidney became the main center of trade. Establishment of the Naval Shipyard across the inlet in 1891 had a major impact on the area's economy and much of the lumber used to construct that facility came from the mills around Sidney. In 1892 the people of the county voted to change the location of the county seat from Port Madison to Sidney and in 1903 Sidney was renamed Port Orchard. In addition to sawmills and the shipyard, early industry in Port Orchard included a steam-operated shingle mill and a terra-cotta pottery plant. Later many of the local industries were destroyed by fire and today the economy is based primarily on the Puget Sound Naval Shipyard.

Port Orchard is the center of commerce for southeastern Kitsap County and is supported by a variety of activities beside the shipyard, such as dairying, raising of livestock and poultry, growing of berries, fruits, bulbs, holly and Christmas trees, and harvesting, packing and shipping of cascara bark, huckleberry, salal, sword fern and cedar boughs for use in floral displays.

Before an adequate highway system was developed, Port Orchard was a main terminal for water-borne traffic between the peninsula and the mainland, but today the harbor facilities are utilized primarily by pleasure craft. A sizeable marina and

Figure 5. MEAN ANNUAL WATER BUDGET AT GRAPEVIEW - ROOT ZONE WATER HOLDING CAPACITY OF 10 INCHES.

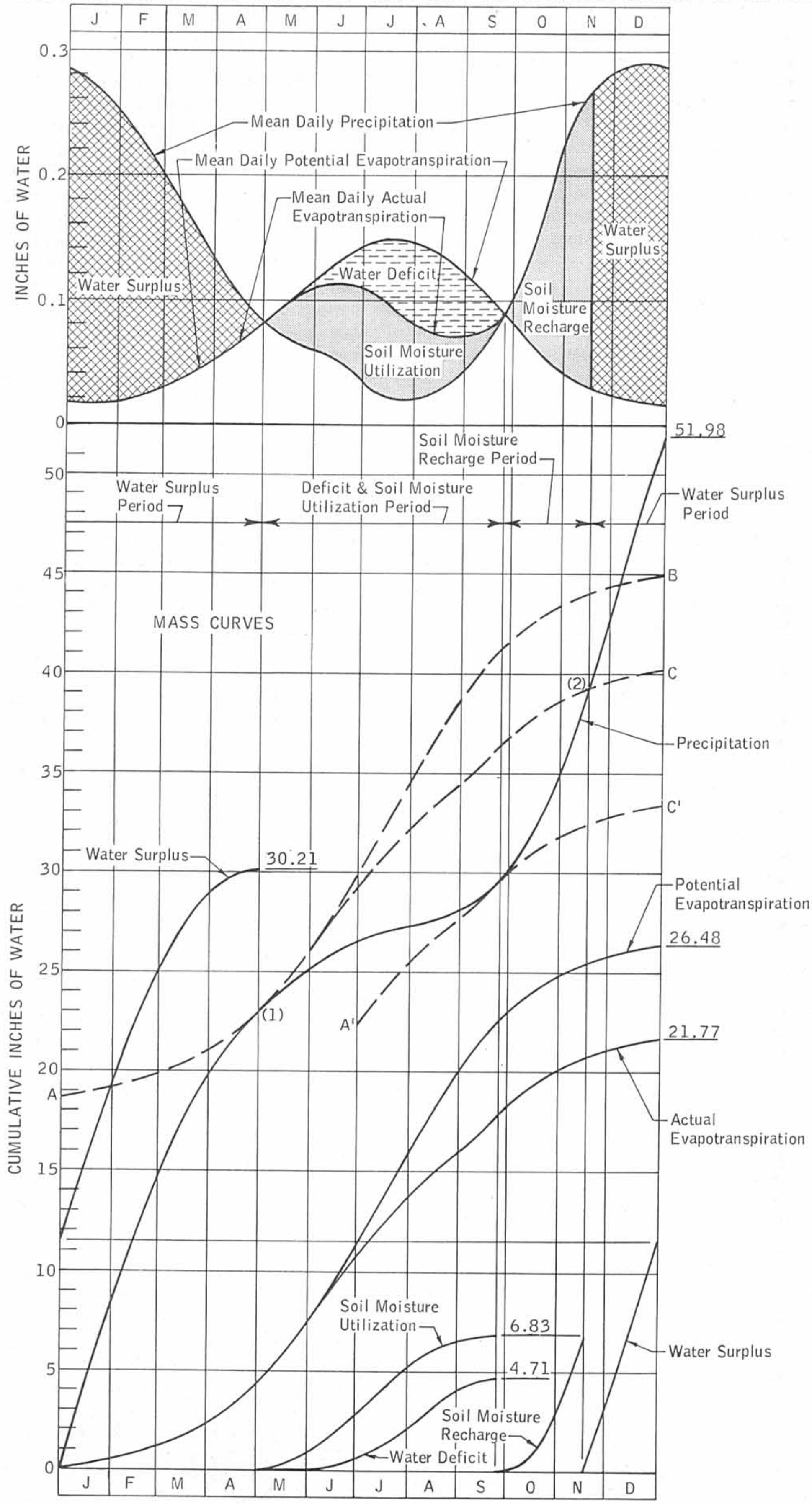


Figure 6. MEAN ANNUAL WATER BUDGET AT GRAPEVIEW - ROOT ZONE WATER HOLDING CAPACITY OF 2 INCHES.

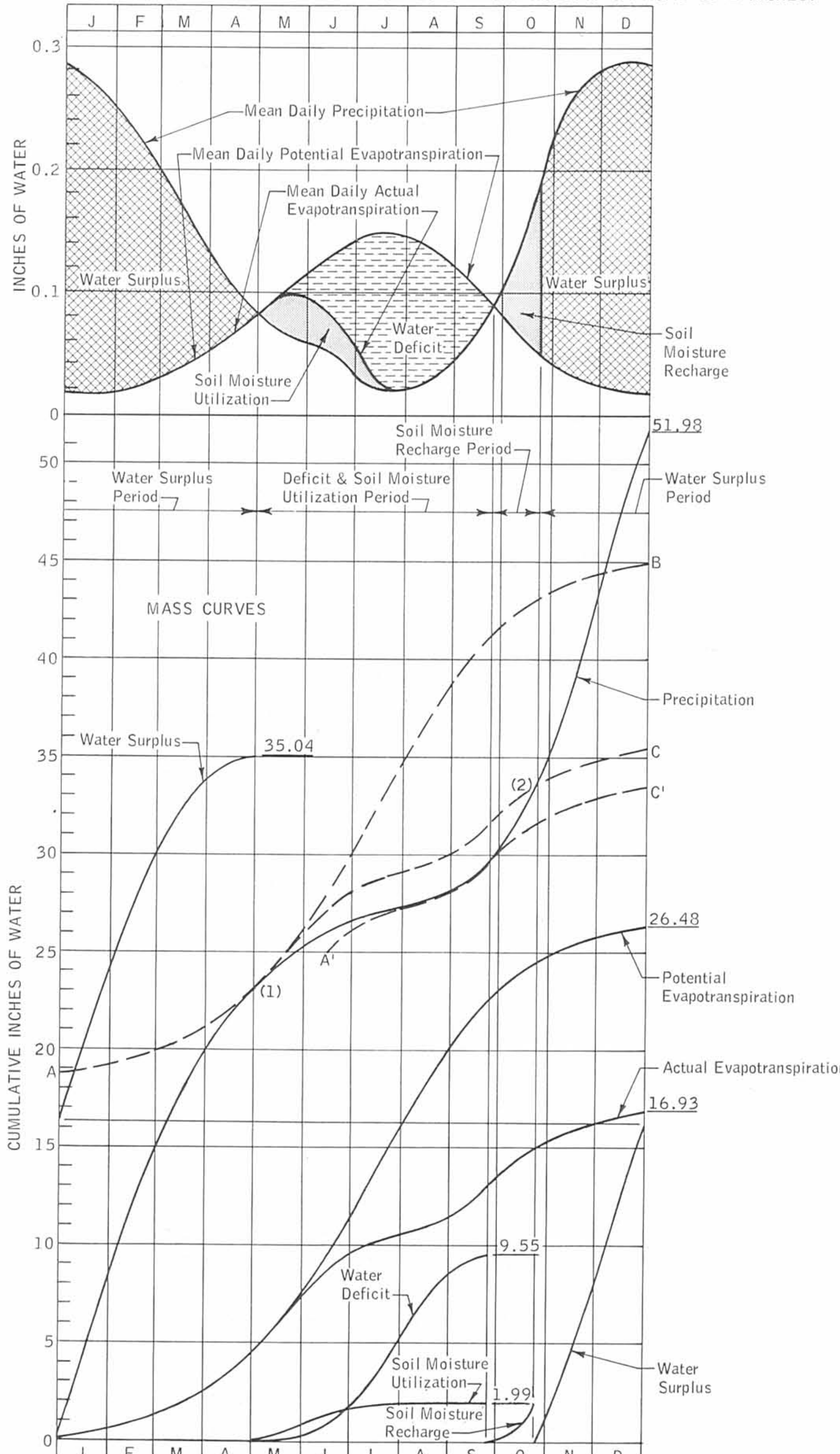


Figure 7. MEAN ANNUAL WATER BUDGET AT PORT TOWNSEND - ROOT ZONE WATER HOLDING CAPACITY OF 10 INCHES.

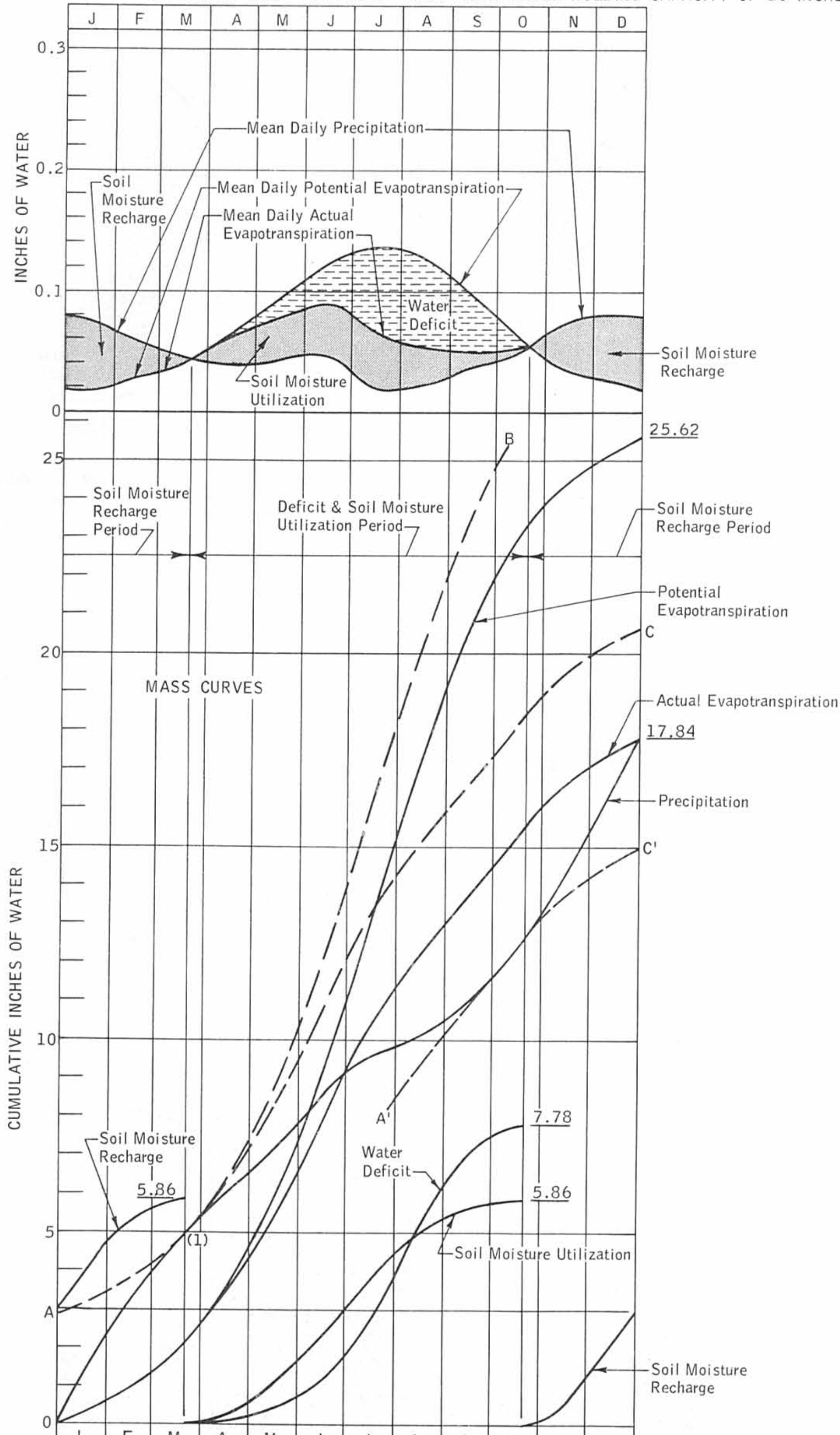
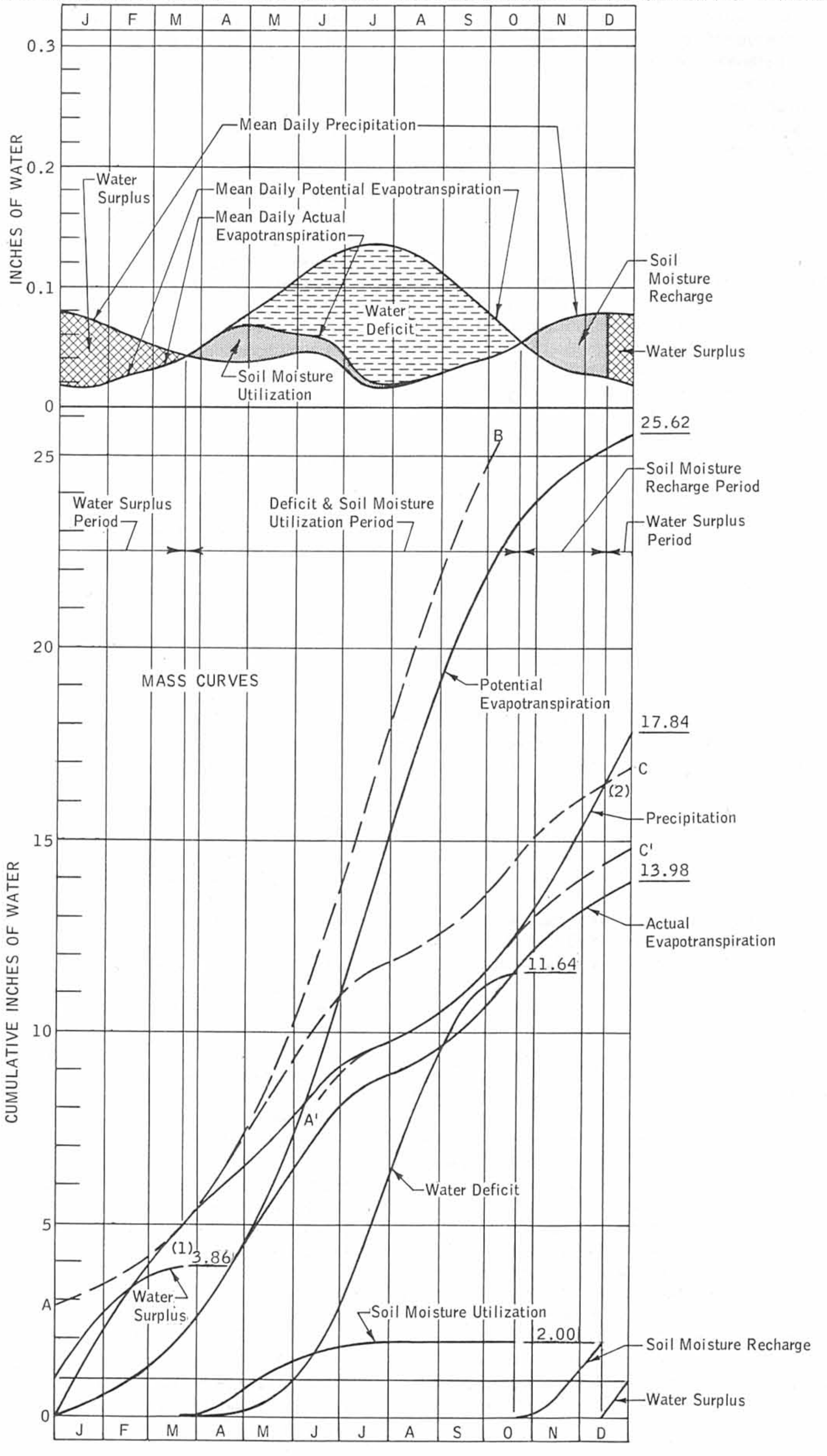


Figure 8. MEAN ANNUAL WATER BUDGET AT PORT TOWNSEND - ROOT ZONE WATER HOLDING CAPACITY OF 2 INCHES.



yacht club have been established in the area, along with a small boat-building works.

Administrative offices of Kitsap County government, along with local branches of various state and federal agencies, are housed at Port Orchard. A large veterans' home and hospital is maintained in nearby Annapolis.

Based on census figures, Port Orchard enjoyed a 20 percent increase in population during the 1950-1960 period and now has about 3300 residents.

Poulsbo

In the late 1800's Poulsbo was settled as an agricultural trade center for the northern part of Kitsap County. The town grew slowly until 1914 when a naval ordinance depot was established by the federal government at nearby Keyport. Most of the personnel stationed at Keyport made their homes in Poulsbo, resulting in an accentuated growth of the community. The base has been used as a torpedo testing station, and in 1944 an ammunition depot was established at Bangor, a few miles to the west. Poulsbo has two oyster companies, a dairy, a meat curing plant, a bulk oil station, and a large marina for pleasure craft and a few fishing boats. The town supports a sizeable business district and has recently become popular as a residence for retired people.

In the 10-year period from 1950 to 1960 Poulsbo enjoyed more than a 48 percent population increase and presently has almost 1600 residents.

Gig Harbor

Soon after reconstruction of the Tacoma Narrows Bridge in 1950 the Gig Harbor peninsula in Pierce County developed into a popular residential suburb of Tacoma. The harbor area has several large marinas, primarily for use of pleasure craft, and also has moorage facilities for boats operated by a commercial fish and oyster company. A small boat-building plant, a gravel company, a bulk-oil plant and a shipping station for huckleberry, salal and fern boughs all help support the economy of the Gig Harbor area.

Census figures indicate that the population of Gig Harbor has increased over 36 percent from 1950 to 1960, and presently the town has a population of nearly 1200 residents.

Winslow

Settlement of Bainbridge Island began in the 1850's and gradually the island developed into a summer resort area for people residing in Seattle. When reliable ferry service was established with the mainland, an increasing number of people became permanent residents on Bainbridge Island and soon the island became known as "Seattle's Bedroom."

The town of Winslow was established at the main ferry terminal site at Eagle Harbor and owes its existence almost entirely to commuter traffic. As highway transportation was improved, Winslow developed a sizeable business district and the town is now the commercial center of Bainbridge Island. An important strawberry and raspberry growing industry has developed on the island and much of this produce is processed by a berry canning, packing and freezing plant located at Winslow. Located across Eagle Harbor from Winslow is the community of Creosote, so named because of a large wood-preservative plant which specializes in the creosote treatment of piling and power poles. Winslow also has a small shipyard, although it is not in operation at present.

Similar to the rapid growth of many other small towns in the report area, Winslow experienced a 44 percent population increase from 1950 to 1960 and now has a population of about 1000 residents.

UNINCORPORATED TOWNS AND RURAL AREAS

Numerous small unincorporated towns and communities are located throughout the report area, primarily as shoreline and harbor resorts and suburban centers. The desirability of waterfront property for its aesthetic value and recreational use has been primarily responsible for the recent rapid growth of such communities. Several older communities owe their existence to earlier establishment as logging and lumbering centers.

Northern Upland

Port Gamble was established in 1853 by Pope and Talbott Lumber Company. The accessibility and abundance of large timber so near the tidal front where the milling and shipping of lumber was easily facilitated resulted in the rapid growth of this town. After the original stand of virgin timber had been removed, the town's economy was bolstered by establishment of the Hood Canal Tree Farm which today provides a sustained yield of timber. The completion of the Hood Canal Floating Bridge in August, 1961, has helped considerably in bringing Port Gamble in closer contact with the mainlands on each side of Puget Sound, and will undoubtedly add to the economy and growth of the area.

Hansville, near the north end of Kitsap Peninsula, owes its origin to the establishment in 1880 of the government lighthouse at Point No Point a mile and a half to the east. The lighthouse is now operated by the U.S. Coast Guard. The small community first developed as a fishing and logging center, but today bases its economy primarily upon summer resort trade. The upland south of the beach community has been logged off in most places and today supports several dairy farms.

Kingston, on the east shore of the northern upland, is a ferry terminal for cross-Sound traffic between Edmonds and the Olympic Peninsula. Numerous small dairy, poultry and berry farms are located on the upland above the town.

Indianola, formerly named Kitsap, is located on the shore of Port Madison in the southern part of the northern upland. Once a terminal for ferries from Seattle, the town is today primarily a resort community and a residential area for commuters who work in Bremerton or on the mainland in Snohomish and King Counties.

Suquamish, like Indianola once a ferry terminal for Seattle cross-Sound traffic, is today primarily a resort and residential community on Port Madison, Nearby, Old Man House, a State historic site, attracts summer visitors interested in the early Indian culture of the Puget Sound region.

Central Upland

The largest unincorporated town on the central upland is Manette, known today as East Bremerton. In 1930, Port Washington Narrows, the channel separating Manette from

Bremerton, was bridged and the residentially developed upland has since been linked with the shipyard economy of Bremerton.

Tracyton, like Manette a residential suburb for many working in the Bremerton shipyard, is also supported by local dairy and berry farms, a fox farm, and has experienced rapid residential growth.

Brownsville and Illahee, two communities located on the east shoreline of the upland, are primarily residential suburbs of the Bremerton area. Illahee State Park offers camping, picnicking and water sports during the summer season.

Keyport was originally developed as a small farming community near the mouth of Liberty Bay. However, in 1910 a government-appointed commission of navy officers selected the area as a site for a torpedo station and by 1914 much of the privately-owned land had been condemned for construction of the government facilities.

Bainbridge Island

Aside from the incorporated town of Winslow, only a few small shoreline communities are located on Bainbridge Island. These include Creosote, Lynwood Center, Fletcher Bay and Manzanita. Small shopping centers located here provide the local markets for these resort and residential communities.

Western Upland

The western upland is sparsely populated except for the well-developed residential areas around Bremerton, Chico and Silverdale located along the shores of Dyes Inlet, and a few isolated beach resort areas on Hood Canal such as Lofall, Seabeck, Tahuya and Belfair. The interior of the upland has a few scattered communities such as Camp Union, but is generally unpopulated, with only a few asphalt-surfaced roads serving the area. Most of the Mason County part of the western upland is covered by a loose network of gravelled roads. Many of these are improved logging roads that follow rather circuitous routes across the logged-off, unpopulated area. A few dairy farms are located along the valley bottoms of the lower parts of the major stream valleys.

The Silverdale-Chico area along Dyes Inlet has developed primarily as a residential suburb of Bremerton. Numerous small farms, which produce eggs, poultry and dairy products, are located on the upland and in the Clear Creek valley adjacent to Silverdale.

Lofall, on Hood Canal at the northern end of the western upland, is a small residential community which, prior to the completion of the Hood Canal Bridge in 1961, was the only ferry terminal linking the Peninsula to the Olympic Peninsula on the west.

Seabeck, Holly, Dewatto and Tahuya are the principal shoreline communities developed along Hood Canal. Although a large number of residents are permanent, the economies of these communities are bolstered considerably by summer resort businesses. Dewatto is a small fishing community that also serves as a log collection center for logging operations along Hood Canal. Holly, so named because of its holly growing and harvesting business, is now predominantly a resort community, with a few permanent residents. Nellita, formerly a sawmill community, is today primarily the home of a few retired residents. The shoreline of Hood Canal from Tahuya eastward to Belfair is almost entirely developed by waterfront residences and summer resorts. Belfair State Park is a major attraction during the summer season, with camping, picnicking and water sport facilities.

The Union River-Gorst Creek valley is occupied by small farms and permanent homes for people who work in the Bremerton-Port Orchard areas.

Southern Upland

The southern upland is populated mostly in the northern part, along Sinclair Inlet in the Port Orchard-Annapolis area, and along Puget Sound in the Manchester-Harper-Southworth area. The Purdy-Burley area and Gig Harbor area in the southern part of the upland have also developed somewhat as farming and residential communities. Most of the southern upland's farmsteads are located in the broader upland valleys of Burley Creek, Blackjack Creek and in the Olalla Creek-Long Lake-Curley Creek valley, with the uplands adjacent to these valleys containing a few scattered farms. Beach homes and summer resorts are located along Colvos Passage, Henderson Bay and Case Inlet.

Aside from the incorporated towns of Port Orchard and Gig Harbor, the major smaller communities are those of Manchester and Harper on Yukon Harbor, Belfair at the head of Hood Canal, Vaughn on Case Inlet, and Burley and Purdy at the head of Henderson Bay. The community of Bethel south of Port Orchard is the only significant center of residential development on the upland. Although most of the shoreline communities originated as logging and lumbering centers, they have since been developed primarily as waterfront residential areas dependent upon retirement incomes, summer resort business, and upon payroll incomes derived from employment in the nearby cities of Tacoma, Bremerton and Port Orchard. The community of Purdy is the site of an oyster canning business, a state pollution control laboratory, and the Peninsula Union High School and nearby Burley produces poultry, dairy products and strawberries.

Vashon-Maury Islands

Much of the economy of Vashon and Maury Islands is derived from commuting residents working in Seattle and Tacoma. Although in the earlier days of water transportation the island business was centered in the community of Burton on Quartermaster Harbor, today's business center has moved inland to the unincorporated town of Vashon. Here are located several small businesses that manufacture such products as tachometers, veterinarian supplies, fiberglass boat hulls and nose cones for military missiles. Also located near the town of Vashon is a large greenhouse. West of town a large orchard produces cherries, apples and pears. Strawberries and cherries are the principal agricultural exports of the island and holly is also raised commercially. Poultry farming is a major industry and over 1,000,000 crates of eggs are shipped annually from Vashon Island. Two radio transmitting stations are located on Vashon Island.

Maury Island is developed principally along its northwestern shoreline by waterfront homes which have access to the protected waters of Quartermaster Harbor. A golf course and county park at Dockton provide recreational facilities on the island. The only large industry is that of a sand and gravel company. This operation has cut deeply into the gravel deposits of the island's precipitous south sea cliff. A radio station has transmitting tower facilities on Maury Island near the community of Portage.

The shorelines of the islands have several small residential and resort communities. These include the ferry terminals of Vashon Heights at the north end where connection is made with Fauntleroy in Seattle and Southworth, and Tahlequah at the south end where ferry connection is made with Tacoma. Other shoreline communities include Burton, Ellisport, Dockton, Portage, Cove, Colvos, and Lizabeula.

Gig Harbor Peninsula-Fox Island

The Gig Harbor peninsula and Fox Island are populated primarily by suburban commuters employed in Tacoma. Reached by the Narrows Bridge, these areas have been developed principally by small upland farms, beach homes and shoreline communities. The town of Gig Harbor is at present the business and population center of the peninsula, although development of the upland adjacent to State Highway 14 north of the Narrows Bridge is rapidly expanding with residential and shopping centers. As of 1963, the upland west of the bridge is being cleared and leveled for the proposed Tacoma Municipal Airport. Fox Island has experienced increasing residential growth with completion of the bridge across Hale Passage in 1954.

Among the small unincorporated communities of this area are Artondale at the head of Wollochet Bay, Rosedale on Carr Inlet, and Arletta on Hale Passage. Kopachuck State Park, located north of Horsehead Bay on Carr Inlet, offers summer camping and picnicking facilities.

Longbranch Peninsula

The Longbranch peninsula, like other upland areas of the report area, has been almost completely logged off with second-growth timber now predominating between the few scattered farms that occupy the cleared areas. The unincorporated shoreline communities of Key Center, Home, Longbranch and Vaughn are the residential centers of the peninsula. A privately owned ferry system operates between the peninsula and Herron Island in Case Inlet. To a lesser extent than on Gig Harbor peninsula and Fox Island, residents commute daily to Tacoma via the Narrows Bridge. Huckleberry and holly are exported from Home. The economy is aided by summer resort business with several marinas offering boating facilities. Penrose Point State Park offers camping, picnicking, and clam digging to summer visitors.

Anderson Island

Reached by ferry from Steilacoom on the Pierce County mainland, Anderson Island is developed only moderately by a few beach homes and summer cabins located primarily along the north shoreline adjacent to the ferry dock, at Amsterdam Bay on the west shore and on the Lyle Point peninsula at Ora Bay. A few small farmsteads are located on the uplands, but the interior of the island is otherwise characterized by uncleared second growth timberland. In earlier days a brick manufacturing industry operated in the Ora Bay area, but today the economy of Anderson Island is based upon development as a commuter suburb of Tacoma.

AGRICULTURE

Early settlements on the Kitsap Peninsula were dependent primarily upon trade with the mainland for their existence, but as more land was cleared, a diversified agriculture developed to satisfy the growing local market. Though of less importance than the shipyard and the forest products industries, agriculture has progressed steadily and presently occupies an important place in the area's economy.

The best agricultural lands on the Kitsap Peninsula and nearby islands are found along the major alluvial-filled stream valleys and throughout much of Bainbridge Island. The agricultural soils are mainly class 3 sandy Alderwood loams and Kitsap silt loams, and are classified as being moderately good (Wildermuth and others, 1934). Other areas are mantled with glacially-derived soils of the Everett and Indianola loam groups and are classified as being excessively droughty.

Most farms in the area are medium to small in size primarily because of high land values, varied topography and sharply differing soil types. Many of the farms are operated on a part-time basis by residents who are employed full time elsewhere. In general, the farms are quite diversified in their output which includes dairy and poultry products, livestock, hay, silage, grains, berries, fruits and vegetables.

MANUFACTURING

Ship construction with associated repair and maintenance is the most important industry on the Kitsap Peninsula. Figures obtained in 1950 show that nearly 40 percent of the employed population in Kitsap County were engaged in manufacturing, and most of these people worked at the Puget Sound Naval Shipyard at Bremerton. This operation is directly dependent upon federal funds and to a great extent controls the economy of the area.

Other small scale manufacturing operations consist of several boat-building firms, a concrete pipe and septic tank construction plant, an aluminum door and window frame manufacturer, several ceramic shops, a trailer manufacturing firm, and several smaller manufacturing companies.

FOREST PRODUCTS

The first lumber mills were established on the Kitsap Peninsula at Port Gamble, Seabeck and Waterman in the early 1850's. Gradually the vast stands of easily accessible virgin timber were removed from the surrounding areas.

The relative importance of lumbering began to decline after the naval shipyard was established at Bremerton, although today the lumbering industry is still of economic importance to the report area. The mills at Port Gamble and Bremerton are presently the largest operators, although more than 25 smaller mills and approximately 150 logging firms operate throughout the peninsula.

Second-growth timber is today utilized for pulpwood, lumber, poles and piling and these are the most important forest products of the area. In recent years Christmas tree growing and brush picking for use in floral displays have also become important secondary forest industries.

MINERALS

Proven mineral deposits in the Kitsap Peninsula area have been insignificant and of little economic value with one exception. The vast glacial deposits of sand and gravel found throughout the area are of considerable importance, and aggregate washing and grading plants are found at several locations. Andesite and basalt rock used for various purposes is quarried adjacent to the Bremerton-Gorst highway and at several places in the hills west of Bremerton. Certain clay mineral deposits offer some potential for manufacturing of cement and for refractory purposes, but to date these have not been exploited.

FISHERIES

Commercial fishing boats operate from the Kitsap Peninsula's many ports and harbors, but in general the fishing activity within the report area has declined. Salmon and other saltwater food fish are found throughout the waters of Puget Sound, but commercial fishing activities have been generally restricted to the larger fishing grounds north of the peninsula.

Shellfish are found throughout the waters of the Kitsap Peninsula and oysters are grown commercially at several locations, primarily in the quiet waters of the more southerly inlets.

Many streams on the peninsula are utilized by anadromous fish (plate 5) and the Washington State Department of Fisheries maintains an important experiment station and salmon hatchery near the mouth of Minter Creek.

RECREATION

Situated between the Olympic and Cascade mountains and bounded by several hundred miles of saltwater shoreline, the Kitsap Peninsula affords an excellent combination of recreational opportunities and scenic beauty. Many permanent residents of the area and summer vacationers own attractive waterfront homes. In recent years the development of new resorts and tourist accomodations, catering primarily to fishing and boating activities, have added considerably to the peninsula's economic stability and growth.